

# High-performance serving of large-scale OpenDRIVE datasets using standardized GIS technology

6th Symposium Driving Simulation, 2020-11-05, Virtual Event

Michael Scholz

A satellite image of the Earth, showing a curved horizon and a view of the Arctic region with surrounding landmasses and cloud patterns.

Knowledge for Tomorrow

# German Aerospace Center (DLR)

## Institute of Transportation Systems

A large, curved image of the Earth from space occupies the bottom right portion of the slide. It shows a view of the Earth's surface with blue oceans, green landmasses, and white clouds. The curve of the Earth is prominent, and the image is positioned as if looking down from a high altitude.

Knowledge for Tomorrow

# German Aerospace Center



## Research institutes

- Aeronautics
- Space
- Energy
- Transportation
- Security
- Digitalisation

## Space administration

## Project management agency





# Institute of Transportation Systems

## Key facts

- In Berlin and Brunswick
- Around 220 employees

## Research fields

- Automotive
- Railway systems
- Traffic management
- Multi-modal and public transport

## Area of work

- Fundamental research
- Conception and strategy development
- Prototyping





# Our research infrastructure ...



## ... and our Testbed of Lower Saxony



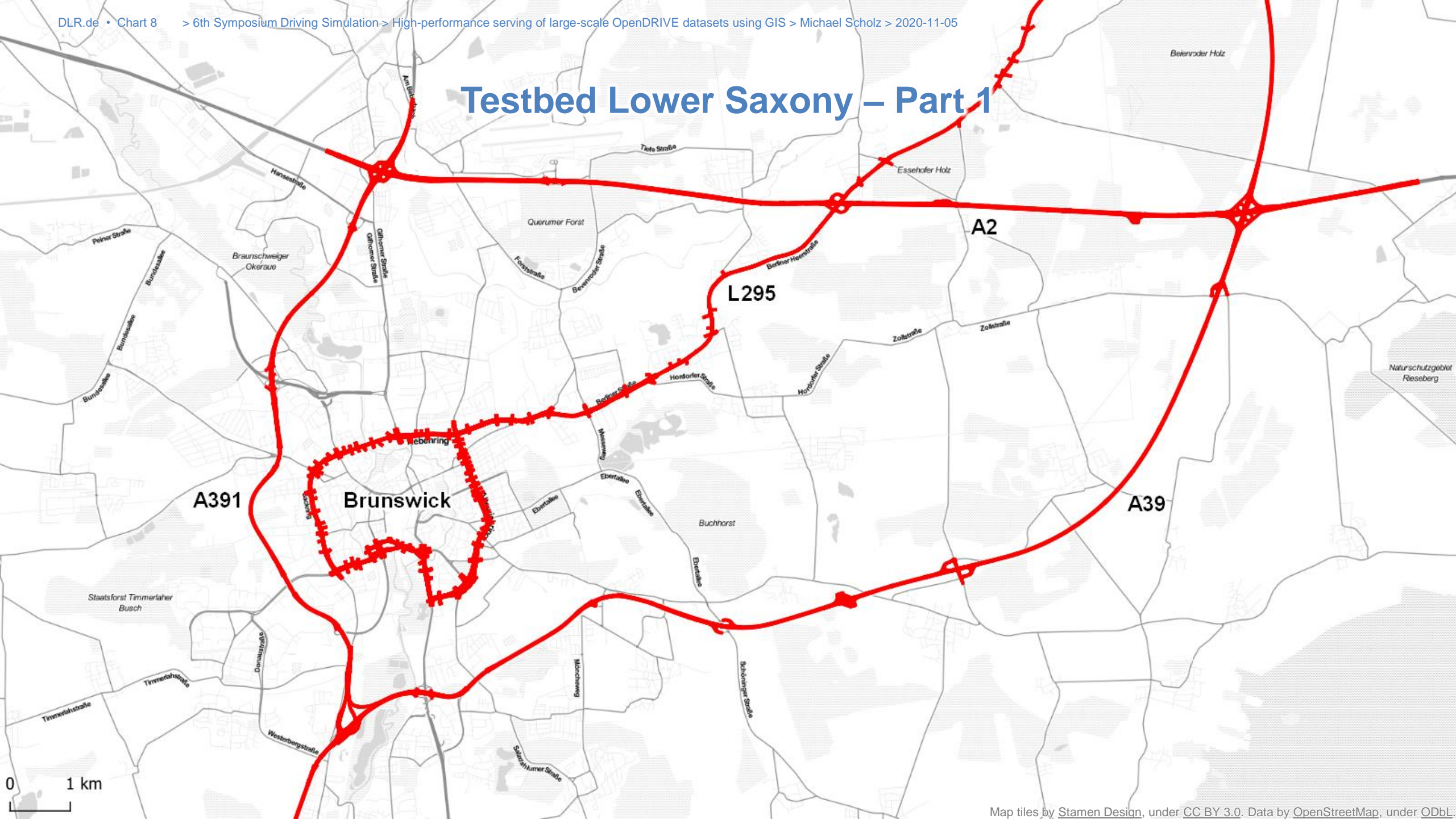


# Challenges

A high-resolution satellite image of the Earth, showing a curved horizon. The visible portion includes the Arctic region with a large white ice cap, surrounding blue oceans, and green landmasses of Northern Europe and Asia. The image is partially obscured by the title text.

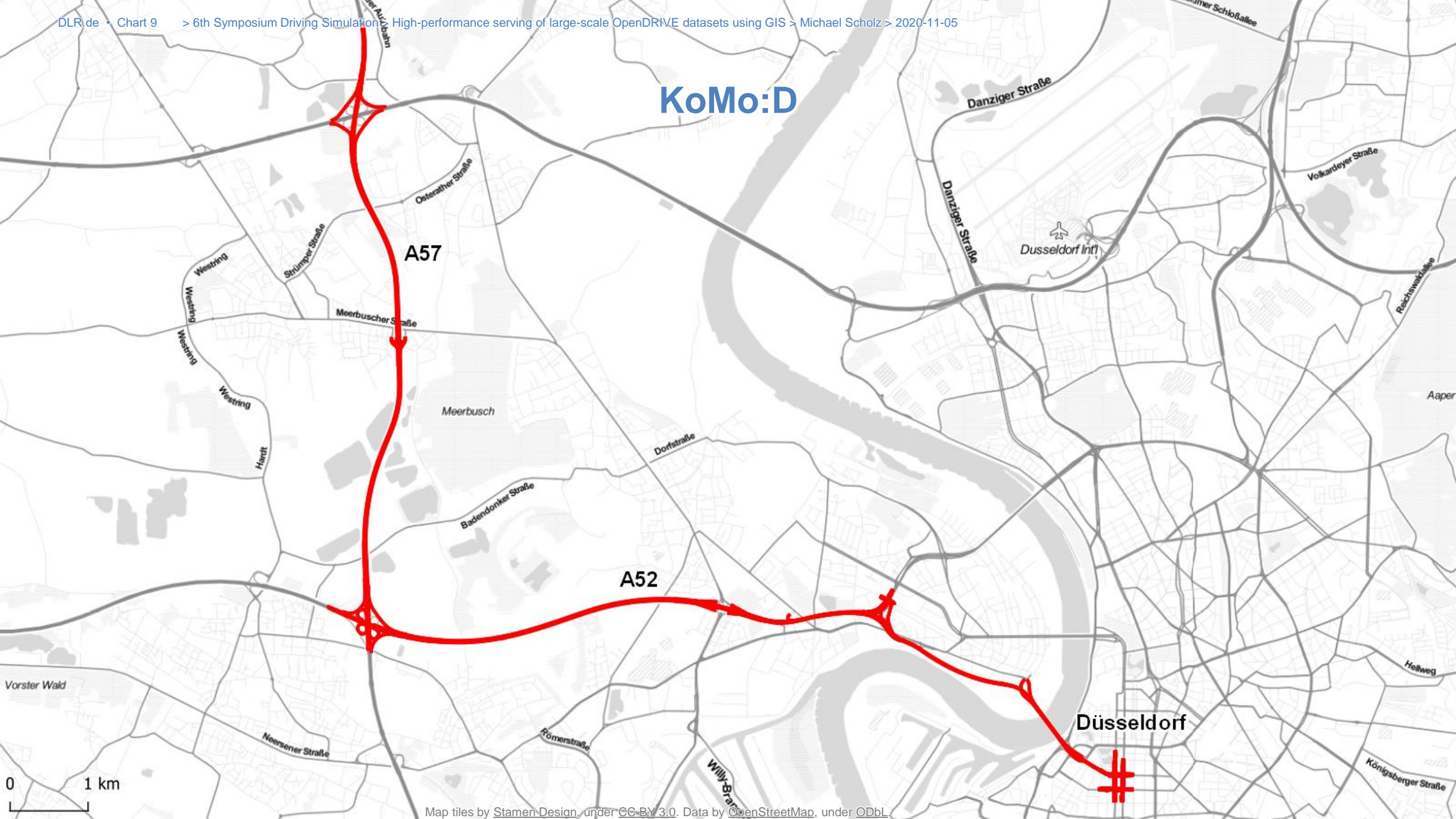
Knowledge for Tomorrow

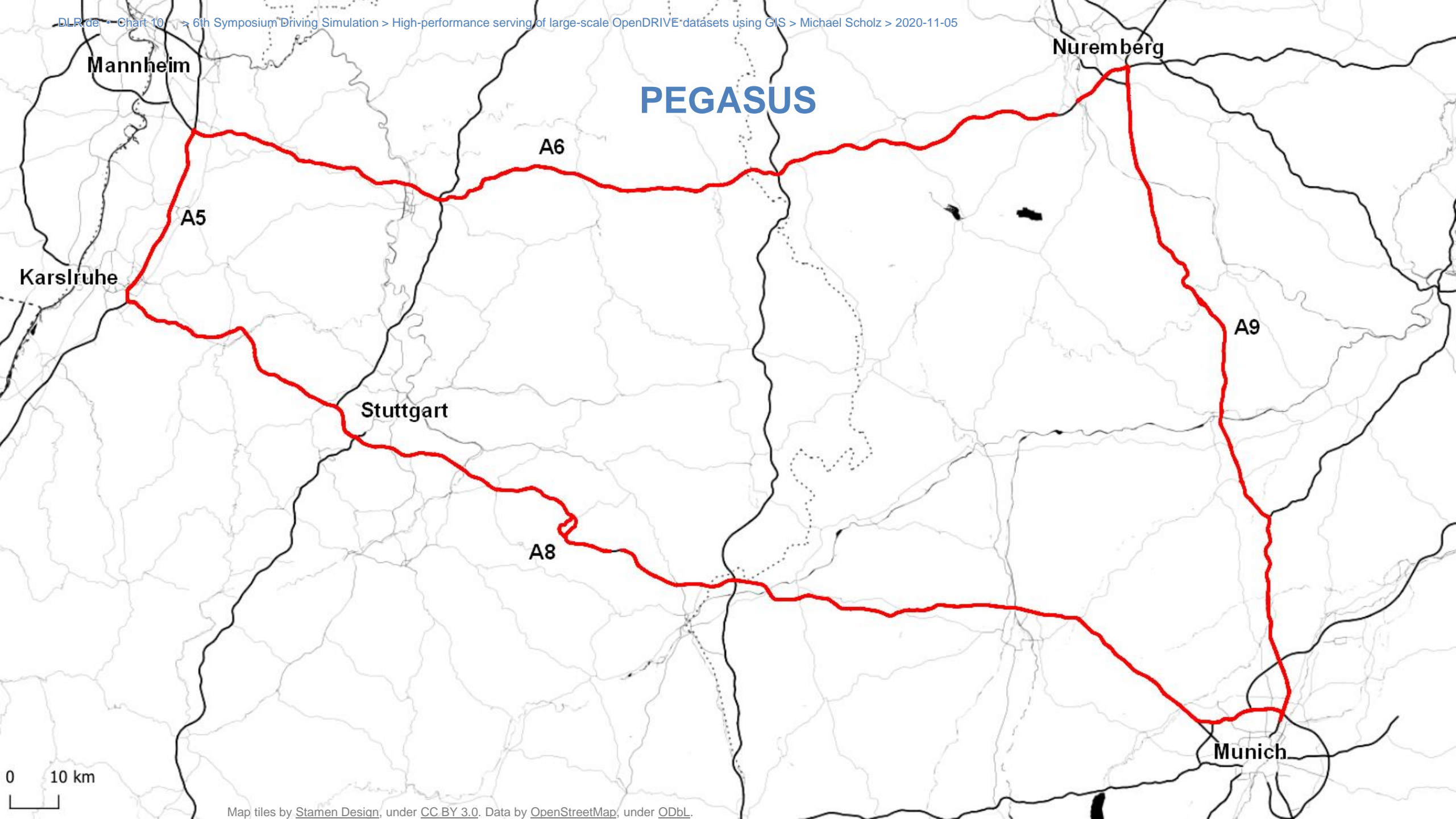
## Testbed Lower Saxony – Part 1





# KoMo:D







# What is desirable?

- Consistent **management** of such *heterogeneous* datasets
- Fast **access** and data browsing for different users
- Simple **interface/API**
- Easy **snippet extraction** from whole datasets



# OpenDRIVE over time

## Initial scope of application

- Fast prototyping of simulation tracks  
→ Artificial/imaginary test data
- Restricted (small) spatial extent
- High modelling detail with visual properties  
→ 3D rendering
- Simple, continuous geometry definition  
→ Smooth road course
- Real-time processing capability

## Current and future trends

- Real-world data
  - From motorways over
  - inner cities to
  - multi-level parking decks
- Data updates and network merging
- Increasing spatial extents
- “From simulation into the car”  
→ Electronic horizon, rejection of styling elements
- Linkage to supplementary environmental data

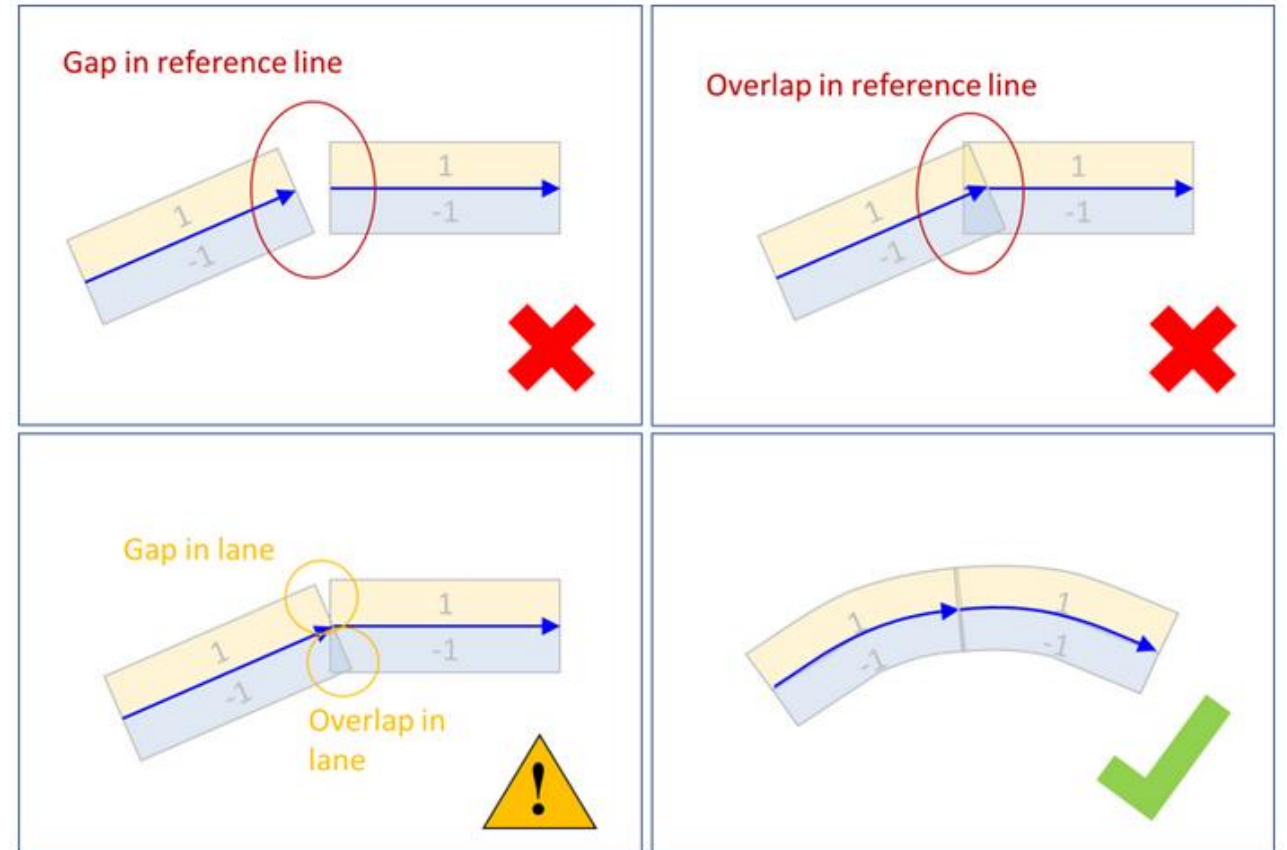




# OpenDRIVE is bad for

## Extracting/editing

- Because you need tools which are
  - commercial (money, money, money),
  - complicated,
  - inflexible,
  - ugly.
- Because there is no server-based solution “as a service”



# OpenDRIVE is bad for

## Data exchange

- Because of strong data model hierarchy and element cross-references

```
<signal s="0" t="0" id="1337"
  country="LV-426" subtype="-1"
  <laneValidity fromLane="1"
</signal>
```

```
<junction name="ne Kreuzung halt" id="1234">
  <connection id="0" incomingRoad="1" connectingRoad="2"
    <laneLink from="-7" to="-7"/>
    <laneLink from="-6" to="-6"/>
    <laneLink from="-5" to="-5"/>
    <laneLink from="-4" to="-4"/>
```

```
<road name="Boulevard of Rock" length="66.6"
  <link>
    <predecessor elementType="junction"
    <successor elementType="junction" ele
  </link>
```

```
<lanes>
  <laneSection s="0">
    <left>
      <lane id="3" type="border"
      <link>
        <successor id="3"/>
      </link>
```





# OpenDRIVE is bad for

## Data exchange

- Because of strong data model hierarchy and element cross-references
- Because small data snippets quickly result in millions of lines of text



```
18 </geometry>
19 <geometry s="3.115631124120e+02"
    "4.333214085751e+00" length="2.07"
20 <paramPoly3 aU="-0.0000000000000000"
    "-1.522623174711e-09" aV="0.0000000000000000"
    dV="1.093841523093e-08" pRange=
21 </geometry>
22 <geometry s="5.192728943920e+02"
    "4.312933712501e+00" length="1.03"
23 <paramPoly3 aU="-0.0000000000000000"
    "-1.086489461279e-09" aV="0.0000000000000000"

eXtensible Markup Language file length : 322.530.389 lines : 2.497.443
```



**Subset extraction is not trivial**





## Solving “the problem” in three steps

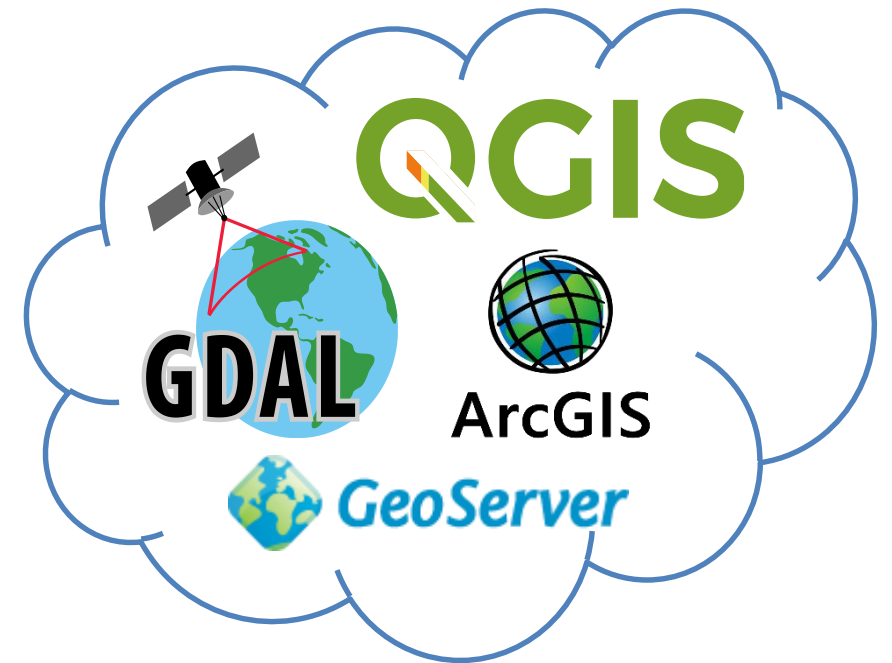
1. Make OpenDRIVE data GIS-able
2. Deploy GIS data in spatial database
3. Publish as RESTful web service

A large, high-resolution image of the Earth as seen from space, showing the curvature of the planet, blue oceans, white clouds, and green landmasses. The image is positioned in the bottom right corner of the slide.

Knowledge for Tomorrow

# GIS? Why?

- Well-established **standards** around for 15+ years (OGC)
- A super-huge **community** of which all automotive guys can just dream about
- They know how to **handle huge data**
- Broad tool support, also **for free** (open source software)
- Some components offer **standardised services**
- Native workflow with cadastral data, CAD, Road2Simulation, Lanelet/2, ...





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**“Don’t re-invent the wheel”**



## Solving “the problem” in three steps

1. Make OpenDRIVE data GIS-able
2. Deploy GIS data in spatial database
3. Publish as RESTful web service

A satellite image of the Earth, showing a curved horizon. The image captures a portion of the Arctic region, with a large, bright white ice mass in the center. Surrounding the ice are swirling patterns of white clouds over a blue ocean. The green landmasses of Europe and Asia are visible on the right side of the frame.

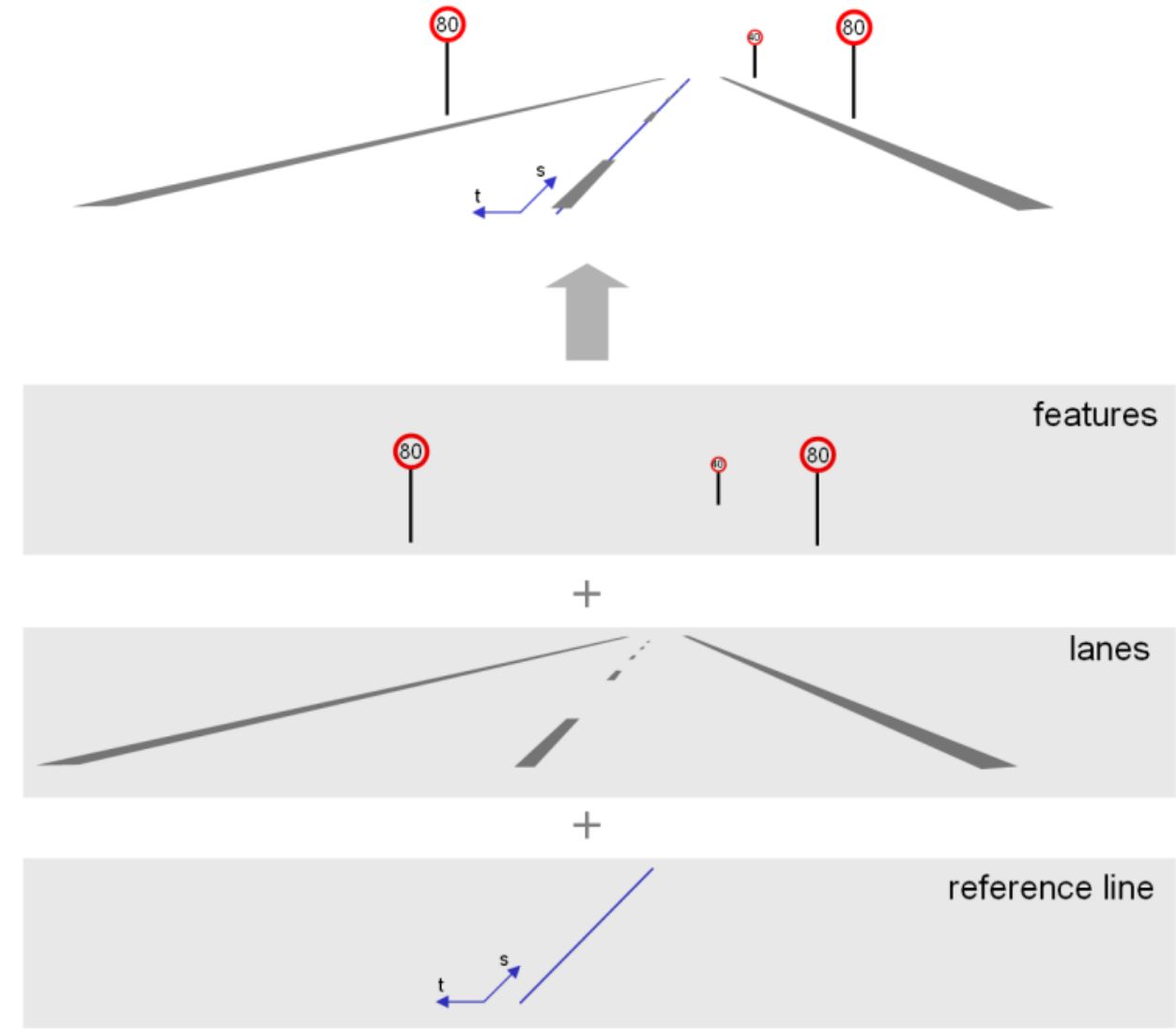
Knowledge for Tomorrow



# Make OpenDRIVE data GIS-able

## Geometry basics

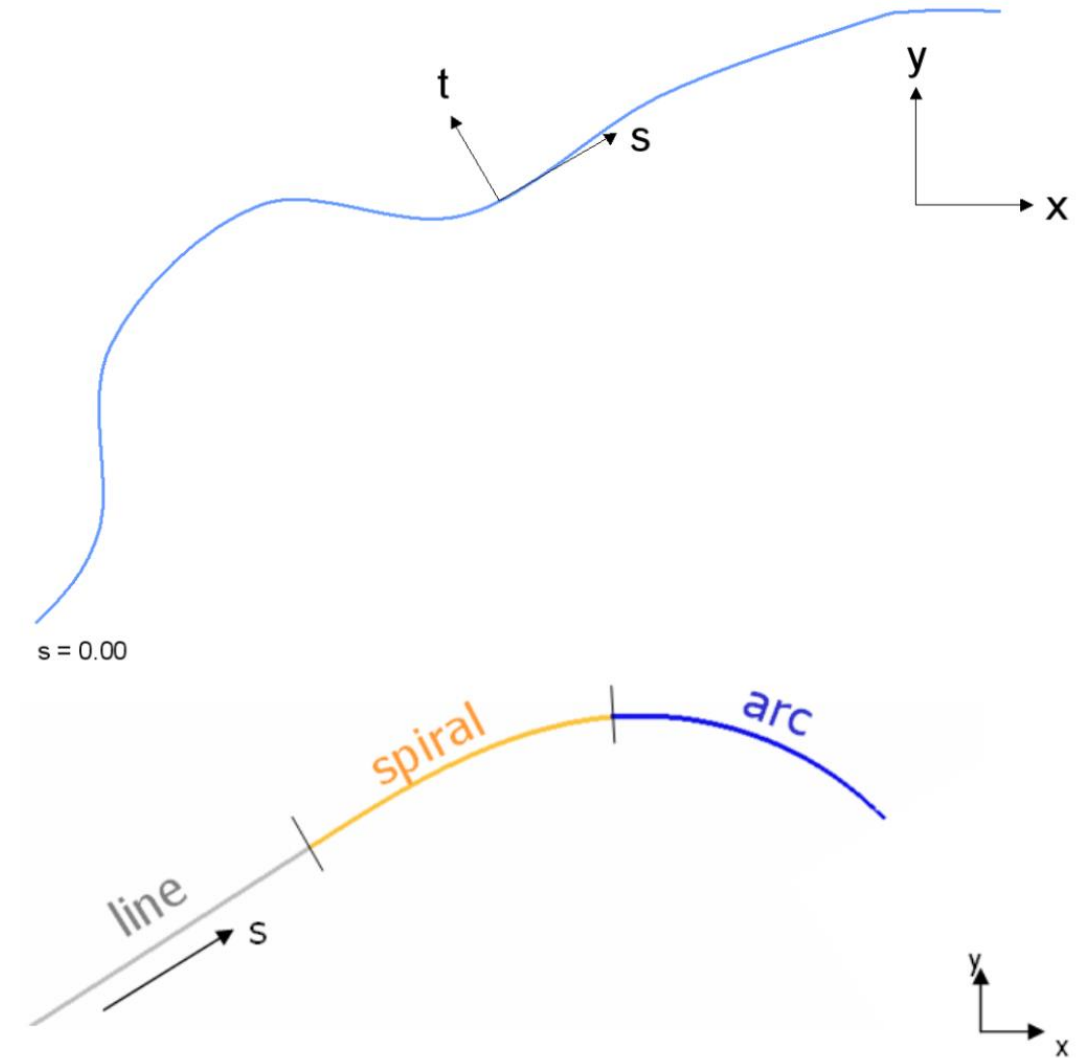
- Elements refer to an imaginary reference line



# Make OpenDRIVE data GIS-able

## Geometry basics

- Elements refer to an imaginary reference line
- Road topography (3D) and topology
  - continuous geometry definition





# Make OpenDRIVE data GIS-able

## Geometry basics: types

```
| | speed  
| | -planView  
| | | -geometry  
| | | | -line  
| | | | -spiral  
| | | | -arc  
| | | | -poly3  
| | | | -paramPoly3  
| | -elevationProfile
```



# Make OpenDRIVE data GIS-able

## Geometry basics: discrete anchor points

```
<planView>  
  <geometry s="0.0" x="604944.1037"  
    y="5792860.1272"  
    hdg="3.5148"  
    length="9.7589">  
    <arc curvature="9.0884E-4"/>  
  </geometry>  
  <geometry s="9.7589" x="604935.03"  
    y="5792856.5285"  
    hdg="3.5237"  
    length="12.0">  
    <line/>  
  </geometry>  
</planView>
```



# Make OpenDRIVE data GIS-able

## Geometry basics: continuous geometry evolution

```
<planView>  
  <geometry s="0.0" x="604944.1037"  
    y="5792860.1272"  
    hdg="3.5148"  
    length="9.7589">  
    <arc curvature="9.0884E-4"/>  
  </geometry>  
  <geometry s="9.7589" x="604935.03"  
    y="5792856.5285"  
    hdg="3.5237"  
    length="12.0">  
    <line/>  
  </geometry>  
</planView>
```





# Make OpenDRIVE data GIS-able

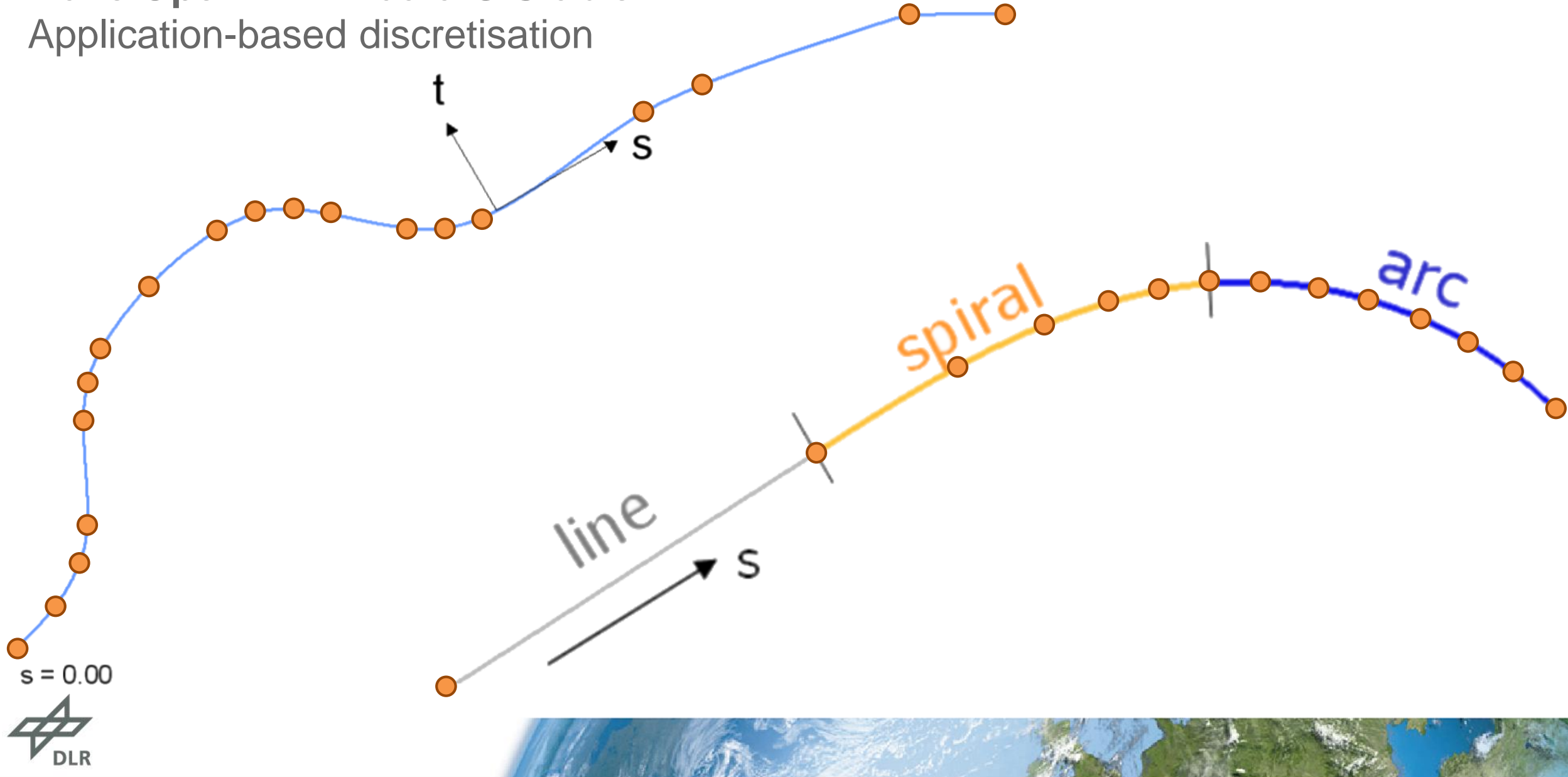
## Application-based discretisation (sampling)

**“Everyone is doing this!”**



## Application-based discretisation

## Application-based discretisation



# Make OpenDRIVE data GIS-able

## OGC Simple Feature primitives



The screenshot shows the OGC website with the following elements:

- OGC Logo:** "OGC® Making location count."
- Navigation Menu:** About ▾, Standards ▾, Innovation ▾, News & Events ▾, Membership ▾, Resources ▾
- Section Header:** Simple Feature Access - Part 1: Common Architecture
- Sub-headers:** 1) Downloads, 2) Related News
- Table:** A table with 4 columns: Version, Document Title (click to download), Document #, and Type. It lists three versions of the OpenGIS Implementation Specification for Geographic information - Simple feature access - Part 1: Common architecture.
- OGC® Standards List:** A list of standards including 3D Tiles, 3dP, ARML2.0, Cat: ebRIM App Profile: Earth Observation Products, Catalogue Service, CDB, CityGML, Coordinate Transformation, Filter Encoding, GML in JPEG 2000, GeoAPI, GeoPackage, GeoSciML, GeoSPARQL, Geography Markup Language, GeoRSS, Geospatial eXtensible Access Control Markup Language (GeoXACML), Geospatial User Feedback (GUF), and GeoTiff.

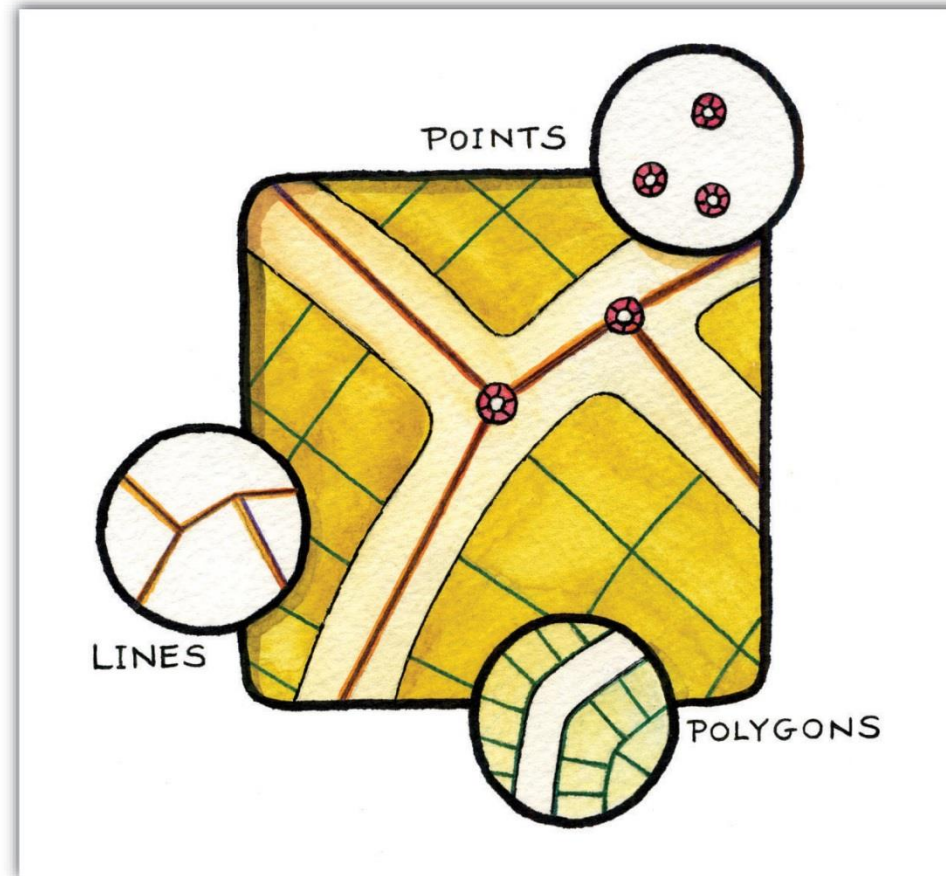
Version	Document Title (click to download)	Document #	Type
1.2.1	<a href="#">OpenGIS Implementation Specification for Geographic information - Simple feature access - Part 1: Common architecture</a>	06-103r4	IS
1.2.0	<a href="#">OpenGIS Implementation Specification for Geographic information - Simple feature access - Part 1: Common architecture</a>	06-103r3	D-IS
1.1.0	<a href="#">OpenGIS Implementation Specification for Geographic information - Simple feature access - Part 1: Common architecture</a>	05-126	D-IS

- OGC® Standards
  - 3D Tiles
  - 3dP
  - ARML2.0
  - Cat: ebRIM App Profile: Earth Observation Products
  - Catalogue Service
  - CDB
  - CityGML
  - Coordinate Transformation
  - Filter Encoding
  - GML in JPEG 2000
  - GeoAPI
  - GeoPackage
  - GeoSciML
  - GeoSPARQL
  - Geography Markup Language
  - GeoRSS
  - Geospatial eXtensible Access Control Markup Language (GeoXACML)
  - Geospatial User Feedback (GUF)
  - GeoTiff



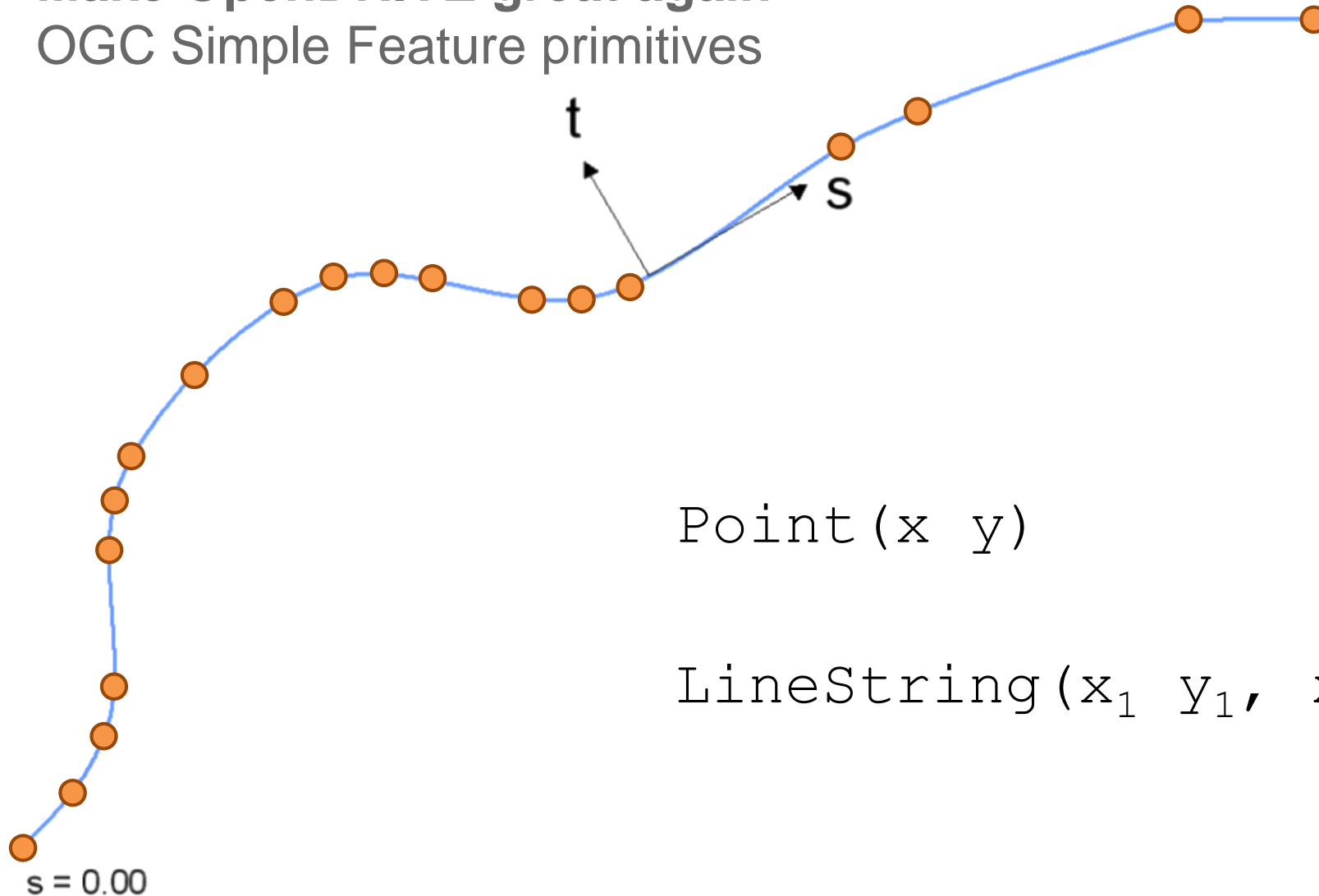
# Make OpenDRIVE data GIS-able

## OGC Simple Feature primitives



# Make OpenDRIVE great again

## OGC Simple Feature primitives



Point (x y)

LineString (x<sub>1</sub> y<sub>1</sub>, x<sub>2</sub> y<sub>2</sub>, ..., x<sub>n</sub> y<sub>n</sub>)



# Make OpenDRIVE data GIS-able

## Translation into Simple Feature model



```
<planView>
  <geometry s="0.0" x="604944.1037"
    y="5792860.1272"
    hdg="3.5148"
    length="9.7589">
    <arc curvature="9.0884E-4"/>
  </geometry>
  <geometry s="9.7589" x="604935.03"
    y="5792856.5285"
    hdg="3.5237"
    length="12.0">
    <line/>
  </geometry>
</planView>
```

```
LineString(
    604944.1037 5792860.1272,
    604752.81 5792819.10, ...)
```

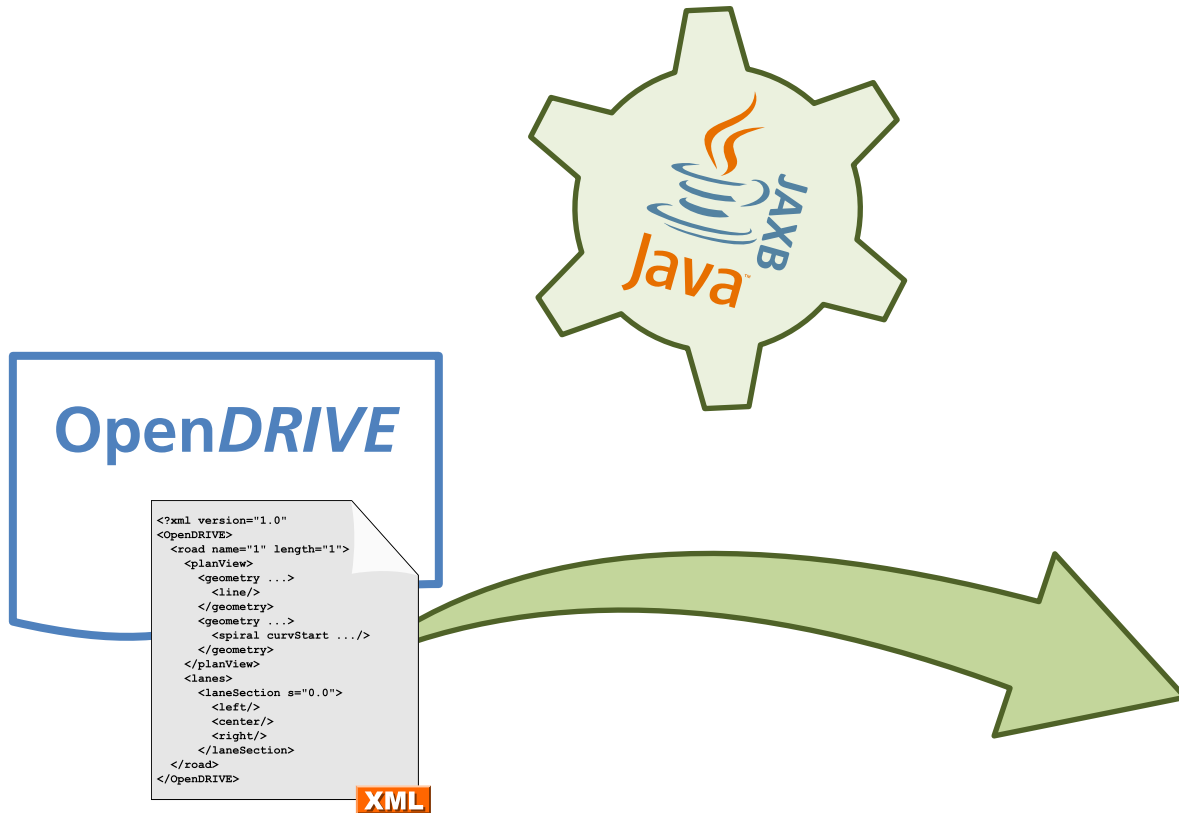
```
LineString(
    604935.03 5792856.5285,
    604754.39 5792810.73, ...)
```





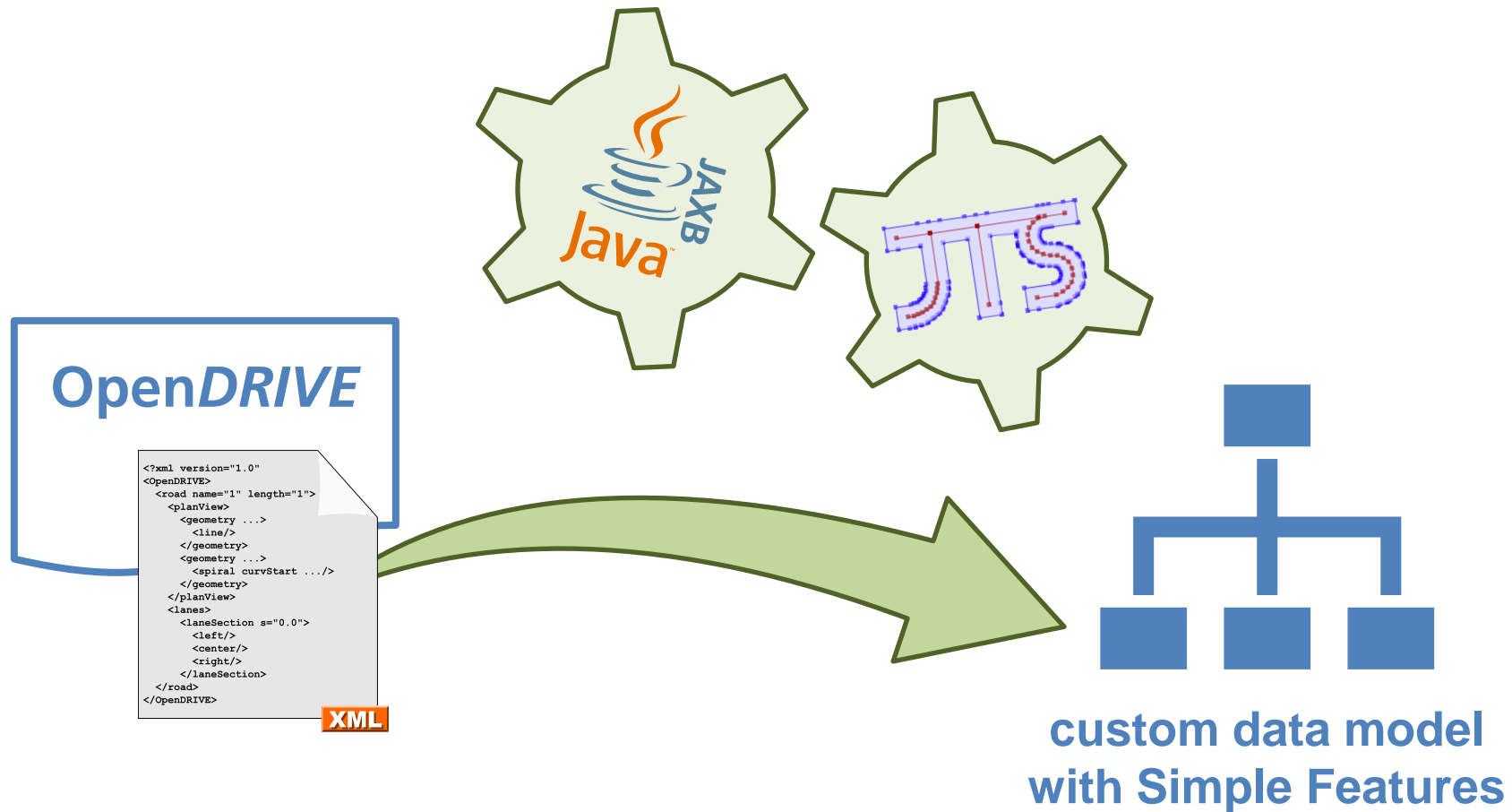
# Make OpenDRIVE data GIS-able

## Data binding to Java



# Make OpenDRIVE data GIS-able

## Geometry discretisation into Simple Feature model



## Solving “the problem” in three steps

1. Make OpenDRIVE data GIS-able
2. Deploy GIS data in spatial database
3. Publish as RESTful web service

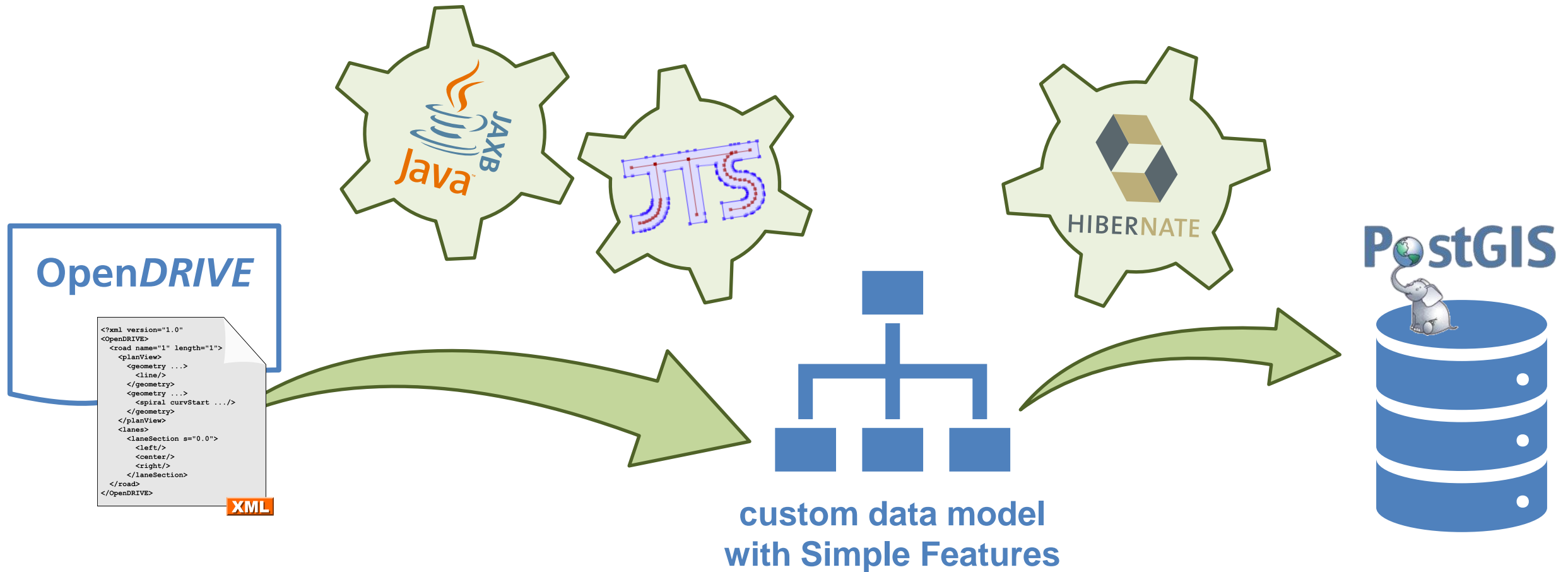
A satellite image of the Earth, showing a curved horizon. The image captures a portion of the Arctic region, with a large, bright white ice mass in the center. Surrounding the ice are swirling patterns of white clouds over a blue ocean. The green landmasses of Europe and Asia are visible on the right side of the frame.

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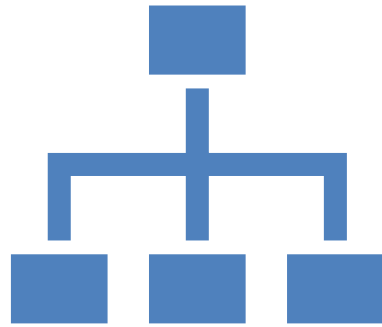
# Deploy GIS data in spatial database

## Persisting through JPA with Hibernate Spatial



# Deploy GIS data in spatial database

## Custom data model



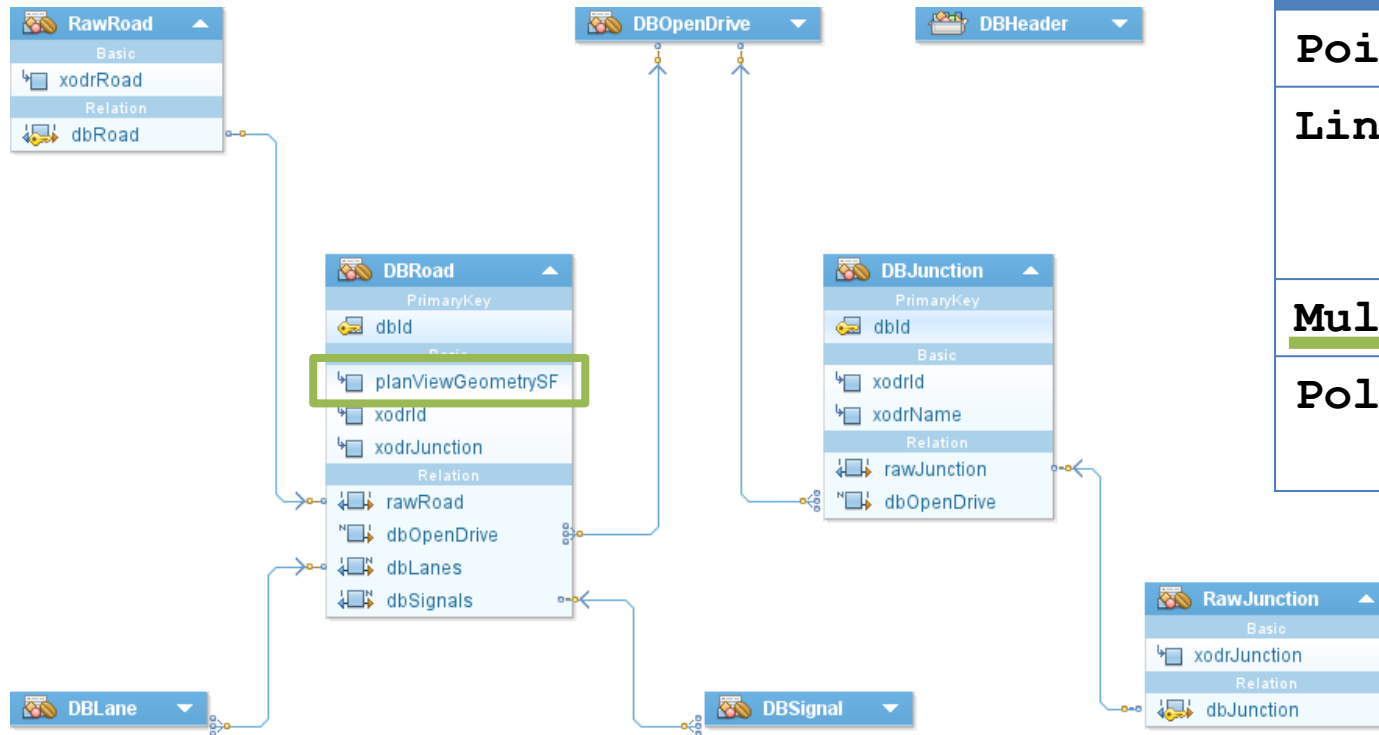
custom data model  
with Simple Features

Simple Feature type	OpenDRIVE element
<b>Point</b>	<signal>
<b>LineString</b>	driving <lane> boundary, <roadMark>, linear <object> (e.g. guardrail)
<b>MultiLineString</b>	road reference line <planView>
<b>Polygon</b>	driving <lane>, <parkingSpace>



# Deploy GIS data in spatial database

## Custom data model



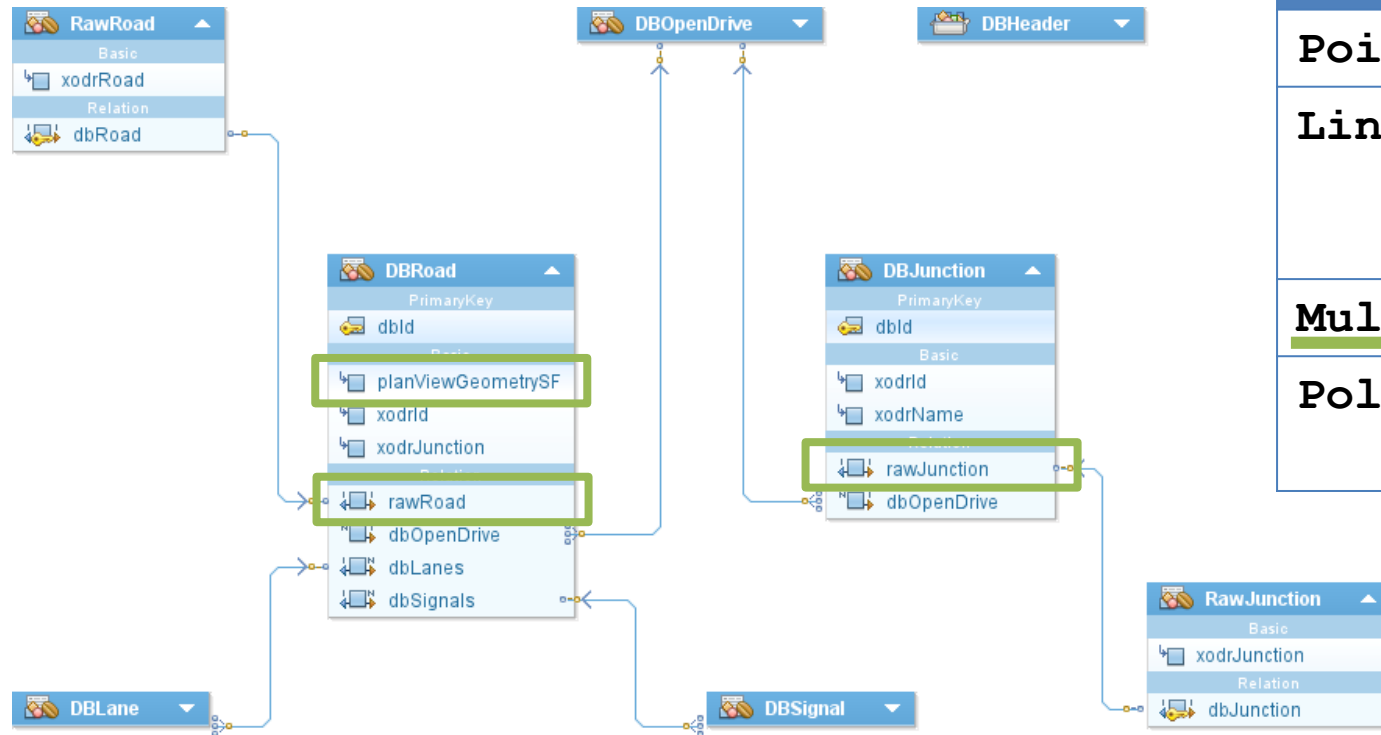
Simple Feature type	OpenDRIVE element
<b>Point</b>	<signal>
<b>LineString</b>	driving <lane> boundary, <roadMark>, linear <object> (e.g. guardrail)
<b>MultiLineString</b>	road reference line <planView>
<b>Polygon</b>	driving <lane>, <parkingSpace>





# Deploy GIS data in spatial database

## Custom data model



### Simple Feature type

### OpenDRIVE element

**Point**

<signal>

**LineString**

driving <lane> boundary,  
<roadMark>,  
linear <object> (e.g. guardrail)

**MultiLineString**

road reference line <planView>

**Polygon**

driving <lane>,  
<parkingSpace>

Additional raw XML elements “attached”

- <road>
- <junction>

## Solving “the problem” in three steps

1. Make OpenDRIVE data GIS-able
2. Deploy GIS data in spatial database
3. Publish as RESTful web service

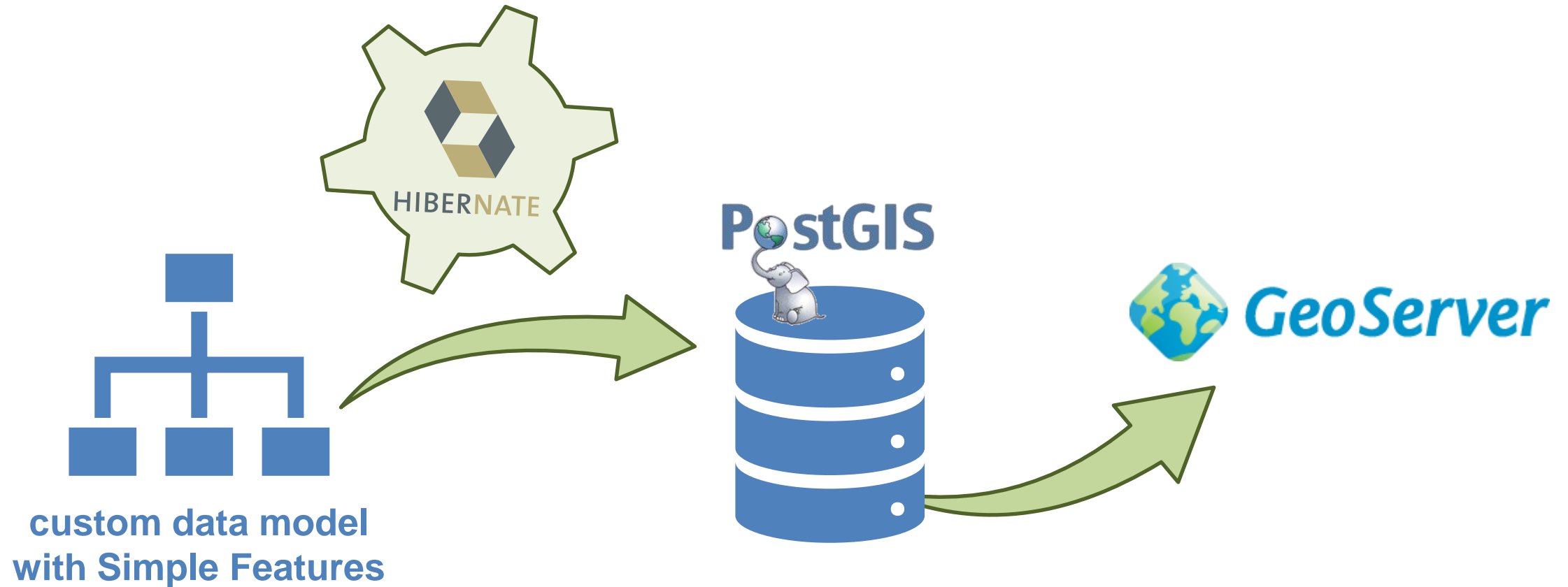


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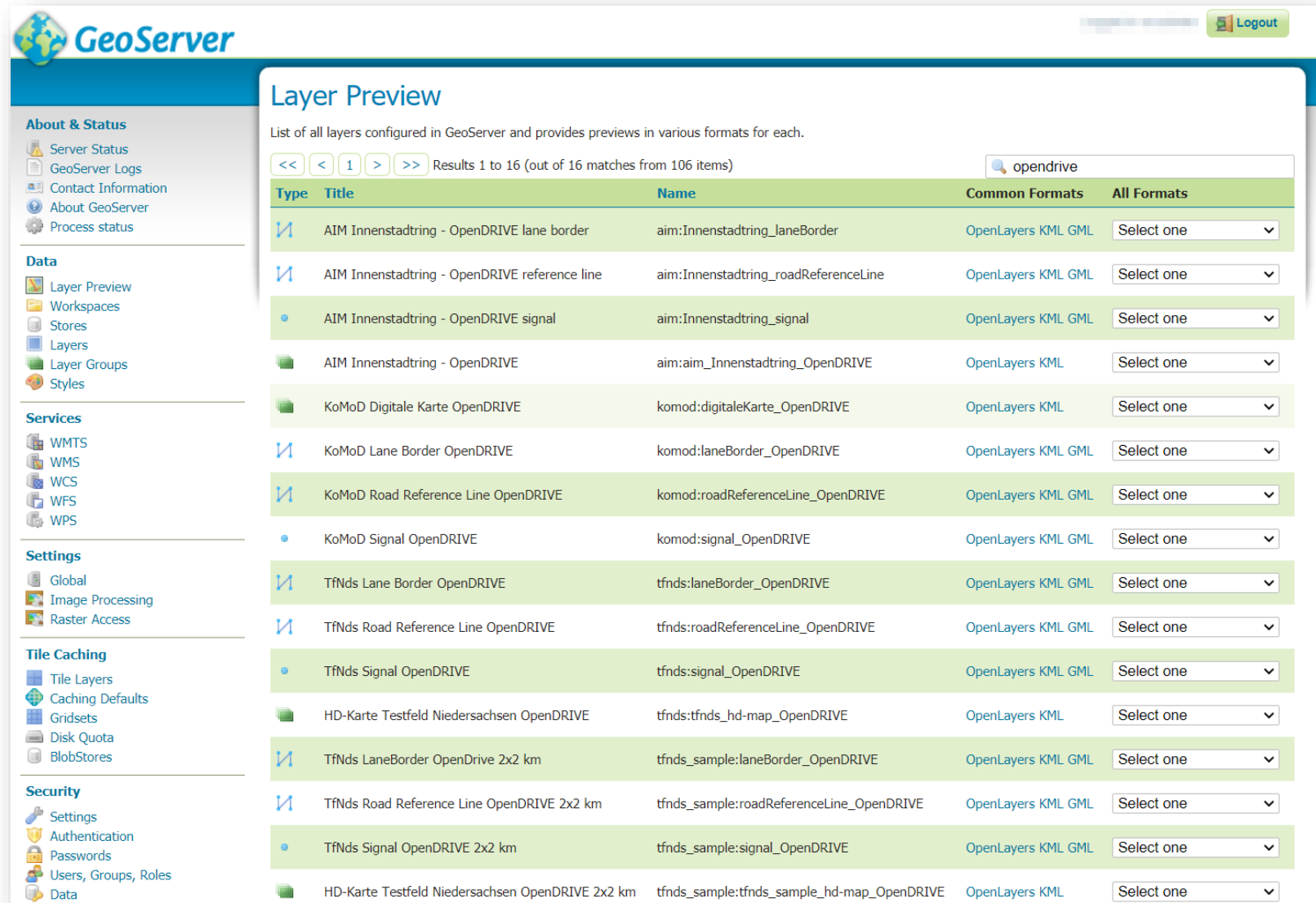


## Publish as RESTful web service

Directly from database through GeoServer



# Publish as RESTful web service



The screenshot shows the GeoServer web interface. On the left is a sidebar with navigation links under categories: About & Status, Data, Services, Settings, Tile Caching, and Security. The main content area is titled 'Layer Preview' and displays a list of layers matching the search term 'opendrive'. The list includes columns for Type, Title, Name, Common Formats, and All Formats. A large green arrow on the left points from the text 'Publish as RESTful web service' towards the 'Layer Preview' section of the interface.

**GeoServer**

**About & Status**

- Server Status
- GeoServer Logs
- Contact Information
- About GeoServer
- Process status

**Data**

- Layer Preview
- Workspaces
- Stores
- Layers
- Layer Groups
- Styles

**Services**

- WMTS
- WMS
- WCS
- WFS
- WPS

**Settings**

- Global
- Image Processing
- Raster Access

**Tile Caching**

- Tile Layers
- Caching Defaults
- Gridsets
- Disk Quota
- BlobStores

**Security**

- Settings
- Authentication
- Passwords
- Users, Groups, Roles
- Data

**Layer Preview**

List of all layers configured in GeoServer and provides previews in various formats for each.

Results 1 to 16 (out of 16 matches from 106 items)

Type	Title	Name	Common Formats	All Formats
Line	AIM Innenstadttring - OpenDRIVE lane border	aim:Innenstadtring_laneBorder	OpenLayers KML GML	Select one
Line	AIM Innenstadttring - OpenDRIVE reference line	aim:Innenstadtring_roadReferenceLine	OpenLayers KML GML	Select one
Point	AIM Innenstadttring - OpenDRIVE signal	aim:Innenstadtring_signal	OpenLayers KML GML	Select one
Image	AIM Innenstadttring - OpenDRIVE	aim:aim_Innenstadtring_OpenDRIVE	OpenLayers KML	Select one
Image	KoMoD Digitale Karte OpenDRIVE	komod:digitaleKarte_OpenDRIVE	OpenLayers KML	Select one
Line	KoMoD Lane Border OpenDRIVE	komod:laneBorder_OpenDRIVE	OpenLayers KML GML	Select one
Line	KoMoD Road Reference Line OpenDRIVE	komod:roadReferenceLine_OpenDRIVE	OpenLayers KML GML	Select one
Point	KoMoD Signal OpenDRIVE	komod:signal_OpenDRIVE	OpenLayers KML GML	Select one
Line	TfNds Lane Border OpenDRIVE	tfnds:laneBorder_OpenDRIVE	OpenLayers KML GML	Select one
Line	TfNds Road Reference Line OpenDRIVE	tfnds:roadReferenceLine_OpenDRIVE	OpenLayers KML GML	Select one
Point	TfNds Signal OpenDRIVE	tfnds:signal_OpenDRIVE	OpenLayers KML GML	Select one
Image	HD-Karte Testfeld Niedersachsen OpenDRIVE	tfnds:tfnds_hd-map_OpenDRIVE	OpenLayers KML	Select one
Line	TfNds LaneBorder OpenDrive 2x2 km	tfnds_sample:laneBorder_OpenDRIVE	OpenLayers KML GML	Select one
Line	TfNds Road Reference Line OpenDRIVE 2x2 km	tfnds_sample:roadReferenceLine_OpenDRIVE	OpenLayers KML GML	Select one
Point	TfNds Signal OpenDRIVE 2x2 km	tfnds_sample:signal_OpenDRIVE	OpenLayers KML GML	Select one
Image	HD-Karte Testfeld Niedersachsen OpenDRIVE 2x2 km	tfnds_sample:tfnds_sample_hd-map_OpenDRIVE	OpenLayers KML	Select one



# Publish as RESTful web service

## The power of GeoServer

- Detailed **user management**
- Fine-grained **data security**/access policies
- OGC-standardised **REST API** (this “web thing”)
  - Web Map Service (WMS)
  - Web Feature Service (WFS)
  - Web Processing Service (WPS)
- Data output as image, KML, GML, GeoJSON, CSV, Shapefile, etc.
- Easy **snippet extraction** through custom **extension**
- Benefiting **spatial indices** on data → “fast like hell”
- Scalability
- Integration into most GIS tools
- Bla, bla, bla ...



## *Live demo*

OpenDRIVE through GeoServer

OpenDRIVE in QGIS

OpenDRIVE subset/snippet extraction queries



Knowledge for Tomorrow



## Conclusion: “Don’t re-invent the wheel”

- Geometry discretization should be based on OGC Simple Features
- Benefit from well-established tools in GIS domain:
  - Free/open frameworks for Java, C++, Python, ... and web development
  - Super-easy ad hoc combination with arbitrary geo-data
  - Direct conversion into 100+ other formats: KML, GML, GeoJSON, CSV, Shapefile, SQLite, XLSX, ...  
→ GDAL: “One library to rule them all”
  - Standardized web service interfaces already implemented (OGC WMS, WFS, ...)

**This ecosystem enables fast, large-scale serving of OpenDRIVE**



STADTBELEUCHTUNG 902945

Source: BS | Energy

x: 605 168.6 r: 15  
y: 577 306.24 (UTM)

<https://youtu.be/diEnlUT6HmA>

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E-mail michael.scholz@dlr.de  
Internet www.DLR.de/ts/en

LICHTSIGNALANLAGE 25139

Source: BELLIS x: 605 162.71 r: 15  
y: 577 297.43 (UTM)

VORFAHRT 51236

Source: BELLIS x: 605 156.88 r: 30  
y: 577 298.07 (UTM)

Fahrbahnmarkierung 85736A

Source: Mobile Mapping x: 605 160.78 r: 15  
y: 577 285.07 (UTM)

GEBÄUDE 7267839

Source: Geoinformation Braunschweig x: 605 153.39 r: 0  
y: 577 302.98 (UTM)

GELÄNDEMÖDELL

Source: Geoinformation Braunschweig